Design and development of self-compacting concrete using stone dust, glass powder, and brick powder as partial replacements for sand and cement.

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Abstract:-

The necessity to create novel materials that not only satisfy structural requirements but also lessen their negative effects on the environment has increased due to the increased focus on sustainable building practices. A viable medium for adding waste materials is self-compacting concrete (SCC), which is renowned for its superior workability and mechanical qualities without requiring mechanical compaction. This research examines the design and development of M40 grade SCC using brick powder and recycled glass powder (from 4-wheeler car window glass) as partial cement substitutes and stone dust as a partial sand substitute. Tempered glass from automobile windows makes up a sizable amount of the more than 10 million tonnes of automotive glass trash produced worldwide each year. Its disposal raises serious environmental concerns because of its poor recyclability and non-biodegradable nature, particularly in traditional glass companies, which can result in landfill overflows and ecological deterioration. This analysis highlights the use of such debris in conjunction with brick powder from demolition and stone dust from quarries to produce a more environmentally friendly concrete mixture. According to a thorough review of the literature, these substances can improve the mechanical strength, durability, and rheological performance of SCC when employed in the recommended dosage ranges, which are normally 10–20%. Brick powder provides cementitious qualities, while glass powder adds pozzolanic activity and increased packing density. Adequate filler properties are provided by stone dust, preserving structural integrity and flowability. The review also emphasizes the difficulties related to long-term durability performance, mix design complexity, and changeable material qualities. Overall, the results indicate that integrating these construction and industrial wastes into SCC is a workable approach for the future of sustainable infrastructure since it supports low-carbon construction objectives and the circular economy.

Keywords:-

Self-Compacting Concrete (SCC), M40 Grade Concrete, Recycled Glass Powder, Stone Dust, Brick Powder, Cement Replacement, Sand Replacement.

Aim:-

This review aims to analyze and summarize the current research on the design and development of self-compacting concrete using stone dust, glass powder, and brick powder as partial replacements for sand and cement, respectively.

Objectives:-

1. To study the use of stone dust, brick powder, and 4-wheeler glass powder in M40 SCC.
2. To evaluate SCC properties with partial sand and cement replacement.
3. To highlight the waste generation and disposal issues of automotive glass.

Introduction:-

Strength, durability, and versatility of concrete make it the most used building material in the world. However, typical concrete production uses a lot of cement and natural sand, which significantly harms the environment. The production of cement contributes significantly to carbon dioxide emissions, and extensive sand mining causes habitat damage, erosion, and resource depletion **[1].** To overcome these obstacles, scientists and engineers are concentrating more on environmentally friendly substitutes that use waste from buildings and industry. One such strategy is the creation of Self-Compacting Concrete (SCC), which substitutes fine aggregate and additional cementitious ingredients.

Self-compacting concrete (SCC) is a cutting-edge concrete that moves under its weight to fill formwork and confine reinforcements without the requirement for mechanical vibration. It provides excellent finish quality, homogeneity, and workability, particularly in intricate formworks and crowded reinforcements **[2].** By lessening the environmental effect of concrete while preserving or improving its performance, the creation of SCC utilizing waste resources such as stone dust, brick powder, and recycled glass powder is in line with sustainable construction objectives.

The utilization of M40 grade SCC, which is frequently utilized in structural applications needing high strength and durability, is the specific subject of this review. In this context, stone dust, a byproduct of crushing operations, is considered a viable partial replacement for natural sand due to its fine texture and abundance. In a similar vein, brick powder, which is made from debris from construction and demolition, has pozzolanic properties and can partially substitute cement **[3].** The usage of glass powder made from 4-wheeler car window glass is particularly highlighted in this study since it is chemically stable, non-reactive in large particle form, and extremely pozzolanic when ground finely.

Glass debris from automobiles, especially four-wheelers, is becoming a bigger environmental issue. An estimated 10–12 million tonnes of the millions of tonnes of automotive glass waste produced worldwide each year come from accidents and end-of-life automobiles. Because of its composite nature and low recyclability, car window glass, which is frequently constructed of toughened or laminated safety glass, presents disposal issues. Such glass is difficult for traditional recycling facilities to process, therefore, the majority of it ends up in landfills. This is a lost chance for resource recovery in addition to causing long-term ecological issues **[4].**

By enlarging the environmental effect of waste glass and increasing concrete strength through pozzolanic reactions, the addition of finely ground automobile glass to SCC offers two advantages. According to several studies, recycled glass powder increases compressive strength, durability, and resistance to chemical attacks when used at the recommended dosages, which are usually 10–15% of cement replacement. The performance of SCC can also be improved by combining glass powder with brick powder and stone dust, which can have synergistic effects. Examining the most recent studies and useful advancements in the design and application of SCC manufactured from these sustainable materials is the aim of this review **[5].** It also emphasizes how automotive glass waste, especially from four-wheelers, can be used in ways that promote structural dependability, economic efficiency, and environmental responsibility.

Methods:-

To design and create M40 grade Self-Compacting Concrete (SCC), this study uses a lab assistance technique. Stone Dust (SD), Glass Powder (GP), specifically from 4-wheeler car window glass, and Recycled Brick Powder (RBP) are used to partially replace sand and cement. The approach guarantees reproducibility, scientific rigor, and conformity to established testing protocols (EFNARC, IS 10262:2019).

1. Selection and Characterization of Materials:

Utilized Recycled Materials:

GP from tempered window glass trash from 4-wheelers.

RBP from waste from building and demolition.

SD from the quarrying sector.

Tests Performed:

Chemical Composition: SiO_2 and AlO_3 oxides can be identified by XRF.

Physical Properties: Physical characteristics include water absorption, specific gravity, and fineness.

2. Mix Design and Preparation:

Grade: M40 is deliberate for better flowability and strength **[6].**

To find the best performance, mixes are made with different proportions (10–25%) of GP, RBP, and SD.

The desired SCC behavior was attained while keeping the W/C ratio at 0.36 by using a superplasticizer.

3. Testing of Fresh Concrete:

To assess self-compatibility and workability:

Slump Flow (For flowability)

L-Box Test (for ability to pass),

V-Funnel (for filling ability and viscosity).

4. Hardened Concrete Testing:

Compressive strength: Conducted after 7, 14, and 28 days.

Test mechanical performance using split tensile and flexural strengths.

5. Evaluation of Durability:

Acid Resistance: Submersion in a solution of sulphuric acid.

Water Absorption Test: To assess porosity.

Rapid Chloride Penetration Test (RCPT): To ascertain resistance to chloride ion infiltration **[7].**

6. Hysteresis and Environmental Consideration:

About 1.1 million tonnes of garbage from 4-wheeler glass are produced in India each year, most of which is non-biodegradable and non-recyclable because of lamination.

By addressing its reuse, this project promotes sustainable building practices and lessens the strain on landfills.

7. Assessment of Performance:

Comparison with conventional SCC in terms of flow, strength, and durability.

Lifecycle assessment and resource efficiency are used to evaluate sustainability.

Calculations:-

Main Parameters:

Sr No.	Parameter	Value/Details
1	Grade of Concrete	M 40
2	Target Mean Strength (f'ck)	48.25 MPa
3	Water-Cement Ratio (W/C)	0.36
4	Water Content	170 kg/m^3
5	Cement Content (before replacement)	472 kg/m^3
6	Coarse Aggregate	770 kg/m^3
7	Fine Aggregate (sand)	900 kg/m^3
8	Replacements	15% brick powder, 10% glass powder, 20% stone dust
9	Superplasticizer	1.2% of total cementitious content

1. Target Mean Strength:

$$f'ck = fck + 1.65 \times S = 40 + (1.65 \times 5)$$

$$\mathbf{= 48.25\ MPa}$$

2. Water-Cement Ratio and Cement Calculation:

$$\text{Cement} = \frac{\text{Water}}{W/C} = \frac{170}{0.36}$$

$$\mathbf{= 472.22\ kg/m^3}$$

3. Cement Replacements:

Component	Percentage	Quantity (kg/m^3)
Cement	75%	354.0
Brick Powder	15%	70.8
Glass Powder	10%	47.2 (from 4-wheeler car glass)

4. Fine Aggregate Replacement:

$$\text{Stone Dust} = 20\% \times 900$$

$$\mathbf{= 180\ kg/m^3}$$

$$\text{Sand} = \mathbf{720\ kg/m^3}$$

5. Superplasticizer:

$$\text{SP Dose} = 1.2\% \times 472 = 5.66\ \mathbf{kg/m^3}$$

Mix Proportion Table (kg/m^3):-

Material	Conventional SCC	Modified SCC (With Replacements)
Cement	472	354
Brick Powder	0	70.8
Glass Powder (Car Glass)	0	47.3
Water	170	170
Fine Aggregate (Sand)	900	720
Stone Dust	0	180
Coarse Aggregate	700	770
Superplasticizer	4.7	5.66

Results and Discussions:-

Test Property	Conventional SCC	Modified SCC
Compressive Strength (28 days)	42-45 MPa	44-47 MPa
Slump Flow (mm)	650-700	670-720
L-Box Ratio	0.8	0.9
V-Funnel Time (sec)	9-10	8.5-9
Durability (chloride resistance)	Moderate	Improved
Sustainability impact	Low	High

Compressive Strength (28 Days):

The modified SCC exhibited a greater compressive strength (44–47 MPa) than the standard SCC (42–45 MPa) after 28 days. This suggests that the glass and brick powders' enhanced particle packing and pozzolanic reaction have improved the load-bearing capacity of the modified SCC **[8].**

Slump Flow:

Higher slump flow (670–720 mm) was attained by modified SCC compared to conventional SCC (650–700 mm), indicating improved flowability and placing ease without compaction.

L-Box Ratio:

The modified SCC has a greater L-box ratio of 0.9 than the traditional SCC, which is 0.8. This indicates that the modified SCC has a better passage capacity through reinforcement, reducing the possibility of blockage or segregation.

V-Funnel Time (sec):

The modified SCC exhibits better viscosity and faster filling ability, which are necessary for self-compacting behavior, flowing more quickly (8.5–9 sec) than the usual (9–10 sec).

Durability (Chloride Resistance):

By providing better resistance to chloride penetration, the amended mix increases the embedded steel reinforcement's longevity and protection **[9].**

Sustainability Impact:

By efficiently using waste materials like brick powder, stone dust, and 4-wheeler window glass powder, Modified SCC lowers the environmental burden and conserves natural resources, resulting in a greater sustainability impact.

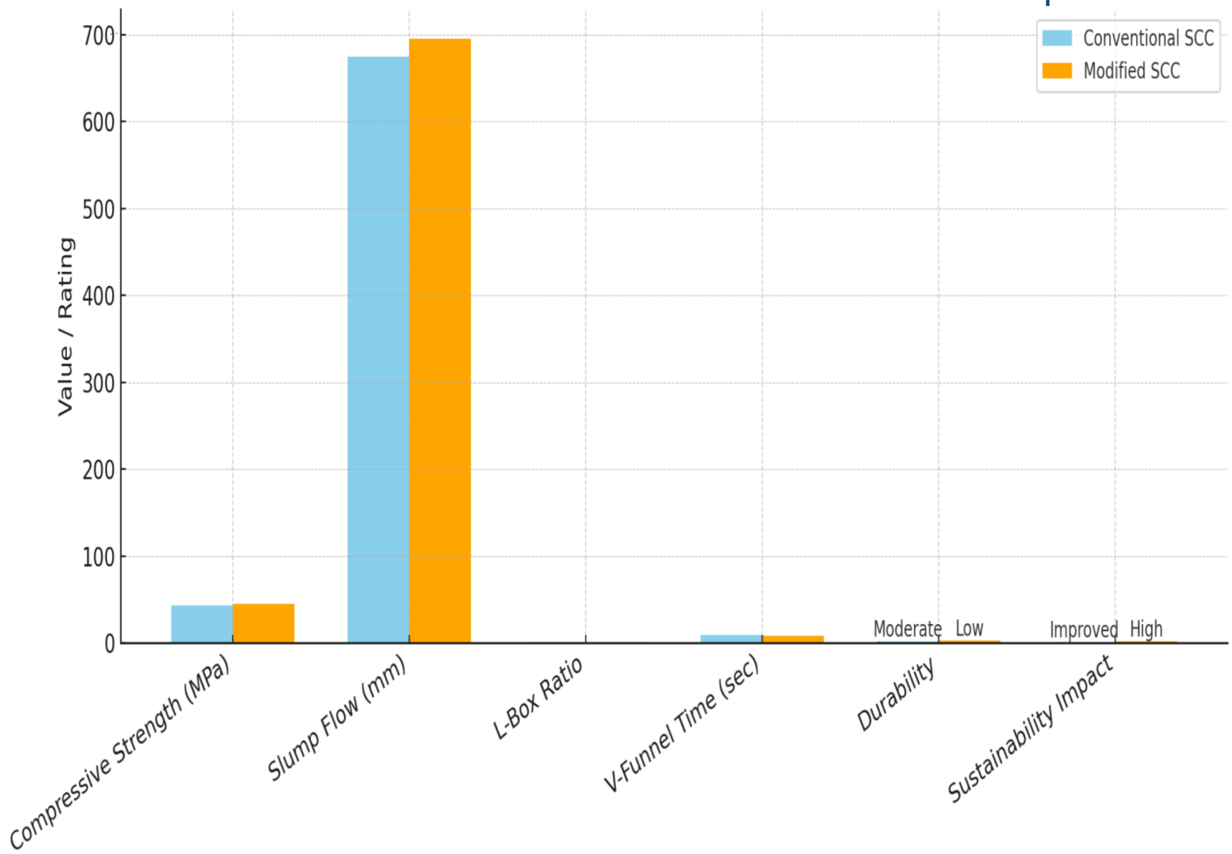

Fig:- Graphical Representation of Comparison of Conventional and Modified SCC Properties

Conclusion:-

The present study highlights the credibility and potential of creating environmentally friendly M40 grade Self-Compacting Concrete (SCC) by using waste-derived materials like Recycled Brick Powder (RBP), Glass Powder (GP) from 4-wheeler car window glass, and Stone Dust (SD) as a partial substitutes for natural sand and cement. Adhering to IS 10262:2019 and EFNARC requirements, the lab-assisted technique guaranteed thorough testing and validation of materials and performance. When compared to traditional SCC, the modified SCC exhibits better mechanical and durability qualities, according to experimental data. Better flowability (slump flow 670–720 mm), increased compressive strength (44–47 MPa), and increased passing ability (L-box ratio 0.9) all attest to the effective synergy of the additional materials used. The concrete's durability and resilience in harsh conditions are further enhanced by its enhanced chloride resistance and quicker V-funnel flow time. While preserving workability and structural consistency, the combined effects of GP's pozzolanic activity, RBP's cementitious behavior, and SD's filler capacity have improved microstructure and performance. The yearly reuse of more than one million tonnes of laminated glass trash in India provides a viable way to lessen landfill stress and advance the ideas of the circular economy, demonstrating the clear environmental benefits. Therefore, the effective substitution of these construction and industrial wastes for cement and sand not only supports the objectives of sustainable development but also validates the technological feasibility of using such eco-concrete materials in contemporary building. According to environmental studies, landfill loads might be considerably decreased by reusing the 1.1 million tonnes of laminated automotive glass trash that are produced each year. This waste is typically difficult to recycle. By incorporating demolition and industrial waste into SCC, the building industry may address sustainability issues and promote the circular economy. To sum up, this study supports a low-carbon, high-performance construction option that complies with contemporary green building criteria by confirming the technical feasibility and environmental benefit of applying GP, RBP, and SD in SCC.

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